Report

HAZUS-MH Riverine Flood Model Validation Study

Washington County, Utah Vicinity

Flood Disaster of January 9-11, 2005

August 15, 2007

FEMA

U.S. Department of Homeland Security
500 C Street, SW
Washington, DC 20472

This document was prepared by

URS Group, Inc.

200 Orchard Ridge Drive, Suite 101
Gaithersburg, MD 20878

FEMA Task Order 379

15702379.00400

TABLE OF CONTENTS

List of Tables

List of Figures

TABLE OF CONTENTS

List of Appendices

The enclosed report includes perhaps the first validation study of the completed **HAZ**ards **U**nited **S**tates-**M**ulti **H**azard (HAZUS-MH) riverine flood loss model. It is based on a loss event that occurred in St. George, Utah on January 9-11, 2005, which took one life and damaged 28 homes along the Santa Clara River. This event provided an opportunity to assess if the HAZUS riverine flood model can predict reasonable losses when compared to a real event.

In the case of the January 2005 Utah flood disaster, the HAZUS riverine loss model was used immediately before the flood event based on forecast peak discharges from the National Weather Service (NWS). The enclosed validation study is based on actual discharges recorded by stream gages and estimated by the U.S. Geological Survey (USGS). However, no other improvements beyond a HAZUS Level I (out-of-the-box) analysis were included other than a user-supplied discharge value. The NWS forecast discharges agreed well with the actual discharges published by the USGS, which suggests that the HAZUS flood model may reasonably forecast damages in future riverine events.

The validation study assessed the performance of the HAZUS loss model along both the Santa Clara and Virgin Rivers in the St. George, Utah area. Along the Santa Clara River through the City of St. George, the HAZUS riverine flood model did a reasonable job in estimating both the extent of the flood hazard and the economic losses to the building stock. The modeled and actual building loss ratios (losses divided by the actual building valuations) were remarkably similar for the Santa Clara River focus area, with both close to a loss ratio of 10%. Loss ratios provide a good method to validate the loss estimation methodology since the uncertainty contributed by different methods of building valuation is removed. However, the Virgin River is characterized by a slot canyon, and the study found that the 10-meter resolution digital elevation model (DEM) available for the region was not detailed enough to allow HAZUS to estimate a reasonable flood extent and depth grid. Therefore, the HAZUS-modeled flooding along the Virgin River using the 10-meter DEM was well outside the limits of what actually occurred and losses estimated by HAZUS along the Virgin River were too high. The resolution of the 10-meter DEM along the Santa Clara River was sufficient to model a reasonable flood extent and depth grid.

This validation study essentially compared a HAZUS Level I riverine loss estimation without potential improvement to estimating the hazard by incorporating enhanced terrain or base flood elevation data using the Flood Information Tool or improving the general building stock and inventory information provided with the HAZUS model. The intent of this study was to determine if HAZUS can produce reasonable loss estimates when applied to a regional riverine flood event. The study also did not adjust the default depth-damage curves to reflect more detailed site-specific conditions. Such an adjustment seemed necessary at the outset of the study since the failure mechanisms of many of the homes was a result of undermining by soil erosion. In those cases, a HAZUS user could revise the depth-damage curves to indicate 100% losses at very shallow depths. The study attributed HAZUS' ability to provide reasonable loss estimates without having to adjust the depth-damage curves to its conservative approach of area-weighting the general building stock losses equally throughout each inundated census block.

The study considered this approach to be conservative since the built area of a census block would generally be concentrated outside the 100-year floodplain, rather than distributed equally as the model assumes. In addition, while HAZUS provides the capability to model losses based on foundation types and elevations associated with a community's participation in the National Flood Insurance Program (NFIP), including their entry date into the program, nearly all the homes damaged in the January 2005 flood event were outside the current, effective 100-year floodplain. The study included HAZUS-modeled losses based on the community's participation in the NFIP since 1974, which demonstrates significant potential savings if the community had more accurate flood hazard mapping.

Future HAZUS riverine flood validation studies should be performed with each major disaster to enhance our capability to estimate damages, perform sound risk assessments, and assess cost-effective mitigation strategies. When funding allows, comparisons should be made at both a regional level and with enhanced local and site-specific data.

Region VIII of the Federal Emergency Management Agency (FEMA) contracted with URS Group, Inc. (URS) to perform a **HAZ**ards **U**nited **S**tates-**M**ulti **H**azard (HAZUS-MH) validation study of the January 9-11, 2005 St. George, Utah flood. This study compares the actual flood event's economic losses and floodplain boundary with a modeled flood's losses and floodplain boundary created with HAZUS-MH software.

HAZUS is a geographic information system (GIS)-enabled natural disaster planning and loss estimation software tool developed by FEMA. The software began as a planning and loss estimation tool for earthquakes and was subsequently expanded to include modules for floods and hurricane winds. HAZUS runs within a GIS environment as an extension to Environmental Systems Research Institute's (ESRI)® ArcGIS™ product. Therefore, HAZUS combines its sophisticated earthquake, flood, and hurricane wind loss estimation and analysis methodologies with the power of GIS' spatial analysis and graphic display capabilities.

HAZUS' loss methodology is built on data collected from past events throughout the United States. The tool is built on sound methodology and available data; however, many assumptions are made regarding the vulnerability of the built environment, the hazard, and the loss estimates. The flood model has the ability to incorporate vastly improved flood hazard and building inventory information — often called a Level II or III study. However, the purpose of this study is to test the performance of the flood model using existing national baseline data sets, or what's known as a Level I analysis.

The recent flood events in the St. George area provided a unique opportunity to determine if the HAZUS loss estimation methodology could be applied to the type of flood events prevalent in Utah. The National Weather Service (NWS) in Utah has, in-place, a sophisticated network of rain gages, Natural Resources Conservation Service (NRCS) SNOTEL (SNOwpack TELemetry) sites, and stream gages that routinely provide estimates of flood parameters prior to events, including discharge estimates expressed in cubic feet per second. The Salt Lake City NWS flood advisory discharge data were obtained by FEMA Region VIII staff just prior to the event. The discharges were then loaded into HAZUS to estimate both the extent of the flood as well as the event's potential economic losses, such as costs to rebuild homes, businesses, and infrastructure like bridges. While the model results indicated that losses and flood boundaries were reasonable when compared to the actual event, it was decided that a more detailed comparison should be completed to further validate the results of the HAZUS flood model.

The City of St. George and surrounding Washington County are located in Utah's "Dixie" region in the far southwestern corner of the state. Washington County is bordered by Nevada on the west and southwest and Arizona to the south. Population estimates from 2004 indicate approximately 110,000 people live in Washington County, with 56,000 of those residing in St. George (US Census Bureau 2006). Figure 1 shows Washington County, cities and towns, highways, principal water features, and those portions of the Santa Clara and Virgin Rivers that flooded in January 2005.

The flood in St. George and surrounding communities occurred over a 3-day period along the Virgin and Santa Clara Rivers in early winter 2005. From January 9-11, the Virgin River basin received record rainfall from thunderstorms associated with a warm and moist Pacific air mass. The warm air and rain also melted some of the early season mountain snowpack in the upper reaches of the Virgin basin (Smart and Havnes 2006). The combination of melting snowpack and heavy thunderstorms resulted in one death and caused substantial damage to communities along both rivers. According to FEMA records, 28 homes were seriously damaged or destroyed by the raging waters. In all, the flood caused a total of $230 million in damages. About $85 million in private property was lost, including acres of pastureland and an estimated $145 million in roads, bridges, parks, and water and sewer lines. Most of the damage was located along the lower Santa Clara River in St. George because the river bisects many neighborhoods.

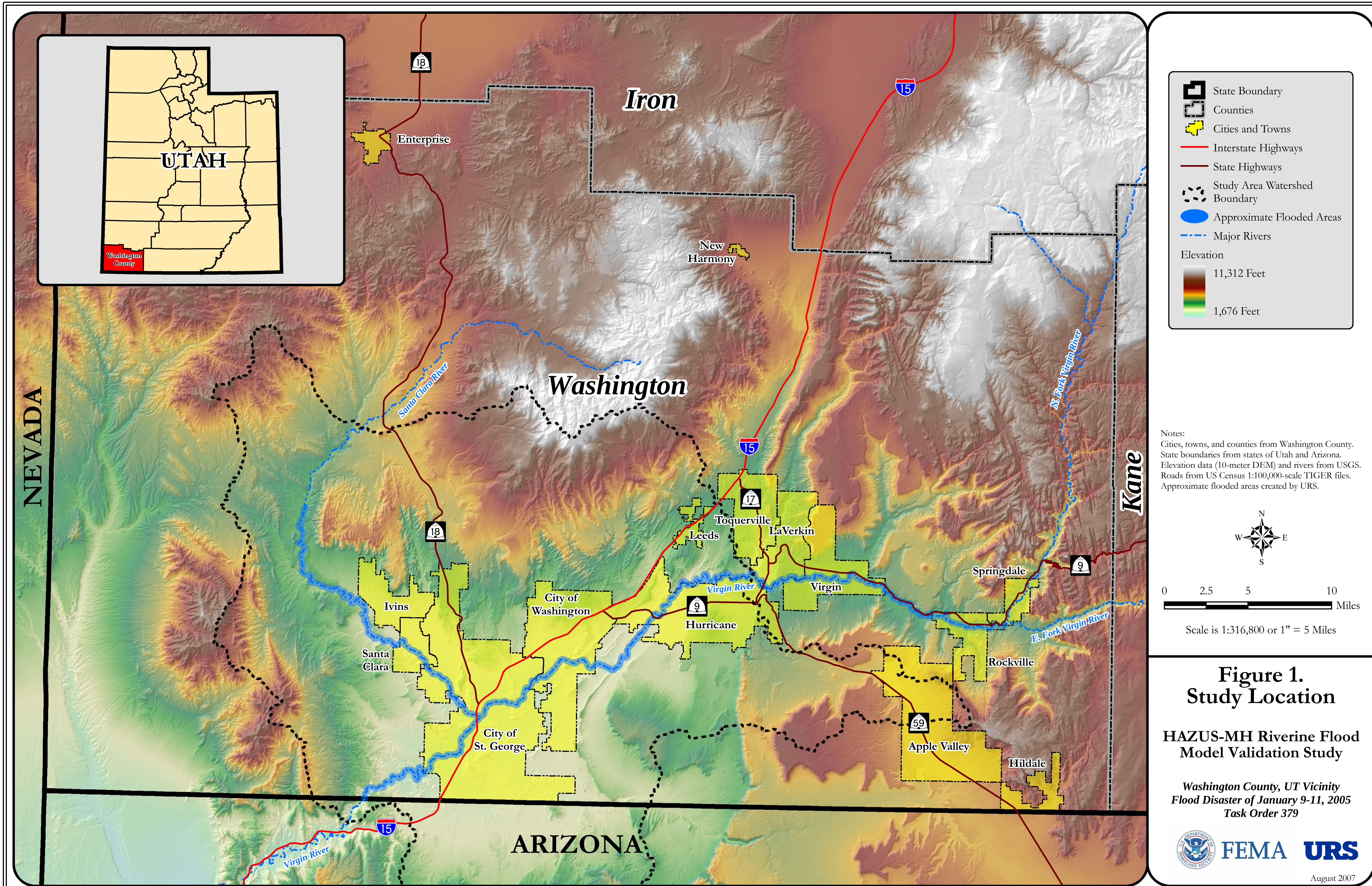


Figure 1. Study Location

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007

This section describes how the validation study was conducted using HAZUS. An overview of the methodology is addressed first, followed by a detailed description of the HAZUS steps followed to model the January 9-11, 2005 flood event. This study compares the actual flood with a flood modeled by HAZUS using the actual event's discharges. And, because there was little difference between the actual event's discharges and the NWS flood advisory, the study validates that HAZUS is a reliable tool to help predict flood boundaries and resulting damages prior to, during, or after events. Lastly, this section describes the comparative analysis between the HAZUS model results and the actual flood event.

3.1 OVERVIEW

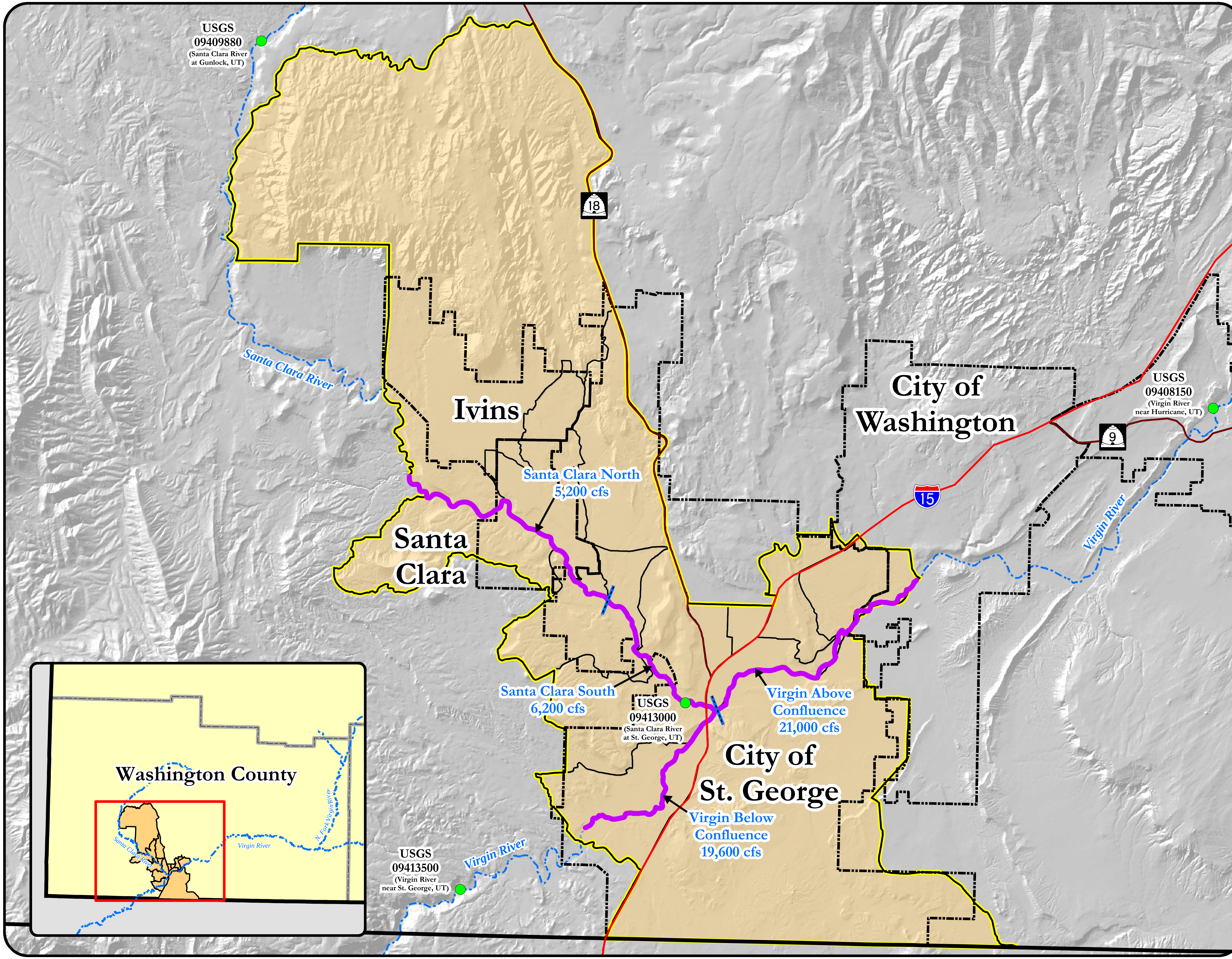
The goal of this study was to assess how well HAZUS could model an actual flood event. Users can supply HAZUS with a variety of inputs to model floods. However, to accurately model a single flood event, it is best to obtain actual discharges at known locations along the impacted watercourses. FEMA created an initial HAZUS model run using a January 11, 2005 NWS flood warning statement to understand where the resultant flooding might be the most extensive. The flood warning, included as Appendix A, projected discharges along the Virgin and Santa Clara Rivers. These preliminary discharges were then used as inputs to run HAZUS.

In April 2005, the U.S. Geological Survey (USGS) conducted a study of the recorded peak discharges at local stream gages during the flood event along the Virgin and Santa Clara Rivers. This study was updated in March 2006 and is included as Appendix B. With the availability of accurate peak discharges at many locations along the Virgin and Santa Clara Rivers, FEMA recognized that a more detailed HAZUS validation study could be conducted. Therefore, FEMA contracted with URS to perform flood recovery mapping and surveying and produce this HAZUS validation study.

3.2 CREATION OF THE HAZUS MODEL SCENARIO

The following section briefly describes how URS created the HAZUS model scenario. Figure 2 shows the study region, census tracts, modeled reaches, gage sites, and discharges used in the model run.

- The study created a HAZUS study region based on census tracts. Census tracts were selected based on the occurrence of flood-related damages. The 12 census tracts selected included 1,140 census blocks to make up the HAZUS study region. A majority of the jurisdictions of St. George, Santa Clara, and Ivins are incorporated within the analysis area.
- Based on the identified study region, the study used HAZUS built-in tools to obtain a 10-meter resolution digital elevation model (DEM) from the USGS. The extent of coverage included all watersheds that feed into the study area.
- A stream network was generated from the DEM using a stream density of 10 square miles (mi^2). Although HAZUS can produce streams from finer densities, 10 mi^2 generated the necessary reaches that caused the damage associated with this event.



State Boundary
Cities and Towns
Interstate Highways
State Highways
Study Region Boundary
Census Tracts
Modeled Reaches
Selected Gages
Major Rivers
Reach Boundaries

Notes:
Cities and towns from Washington County.
State boundary from State of Utah.
Rivers and gages from USGS.
Roads from US Census 1:100,000-scale TIGER files.
Modeled reaches and boundaries created by URS from USGS rivers.
Study region boundary and census tracts from US Census.
Hillshade created by URS from USGS 10-meter DEM.

Peak discharges (i.e. 5,200 cfs) used in this study provided by March, 2006 USGS report (Appendix 2). Units in cubic feet per second.

N
W E
S

0 1 2 4 Miles

Scale is 1:126,720 or 1" = 2 Miles

Figure 2. Study Region

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007

- Individual stream segments were selected from the overall stream network to create a study case. Six reaches along the Santa Clara and Virgin Rivers totaling about 24 miles were selected. Study cases are necessary to create actual flood scenarios and calculate economic losses.
- A flood scenario was created using the updated peak discharges from the March 2006 USGS study (USGS 2006), which is located in Appendix B. Peak discharges from four gages were selected and assigned to the applicable study case reaches to simulate the actual flood event. Once discharges were entered, HAZUS used the discharges and the associated DEM to create flood boundary and flood depth files.
- Lastly, HAZUS calculated economic losses for the following categories:
  - General Building Stock Damage and Loss (for homes and businesses)
  - Essential Facilities (includes schools, hospitals, police and fire stations)
  - Transportation Systems
  - Utility Systems
  - Vehicles
  - Debris
  - Direct Social Loss
  - Indirect Social Loss

Losses were primarily calculated to determine how well HAZUS estimated damages to homes.

3.3 COMPARATIVE ANALYSIS BETWEEN HAZUS AND ACTUAL FLOOD EVENT

Three separate analyses were conducted for this study and each is described in the following section.

3.3.1 Flood Boundary Comparison

The modeled flood boundary from HAZUS was compared with the actual flood event boundary and the FEMA 100-year floodplain boundary effective at the time of the flood. First, URS made a broad comparison of the HAZUS flood boundary and the effective FEMA 100-year floodplain over the entire study case. Figure 3 shows both the HAZUS flood boundary and the effective FEMA 100-year floodplain. The HAZUS flood boundary along the Santa Clara River was determined to be realistic because the flood boundary aligned well with the effective FEMA 100-year floodplain and in most cases was narrower in width and smaller in area. This slightly smaller extent is expected since the estimated return period of the January 2005 event on the Santa Clara River is estimated to be 22 years. However, HAZUS did not perform nearly as well along the Virgin River. Figure 3 clearly shows HAZUS created a flood boundary that was similar in width and, in some cases, much wider than the effective FEMA floodplain, especially upstream of the confluence with the Santa Clara River. Based on this comparison, URS and FEMA determined that HAZUS overestimated the flood boundary along the Virgin River because the 10-meter resolution DEM was not dense enough to adequately model the Virgin River in this area.

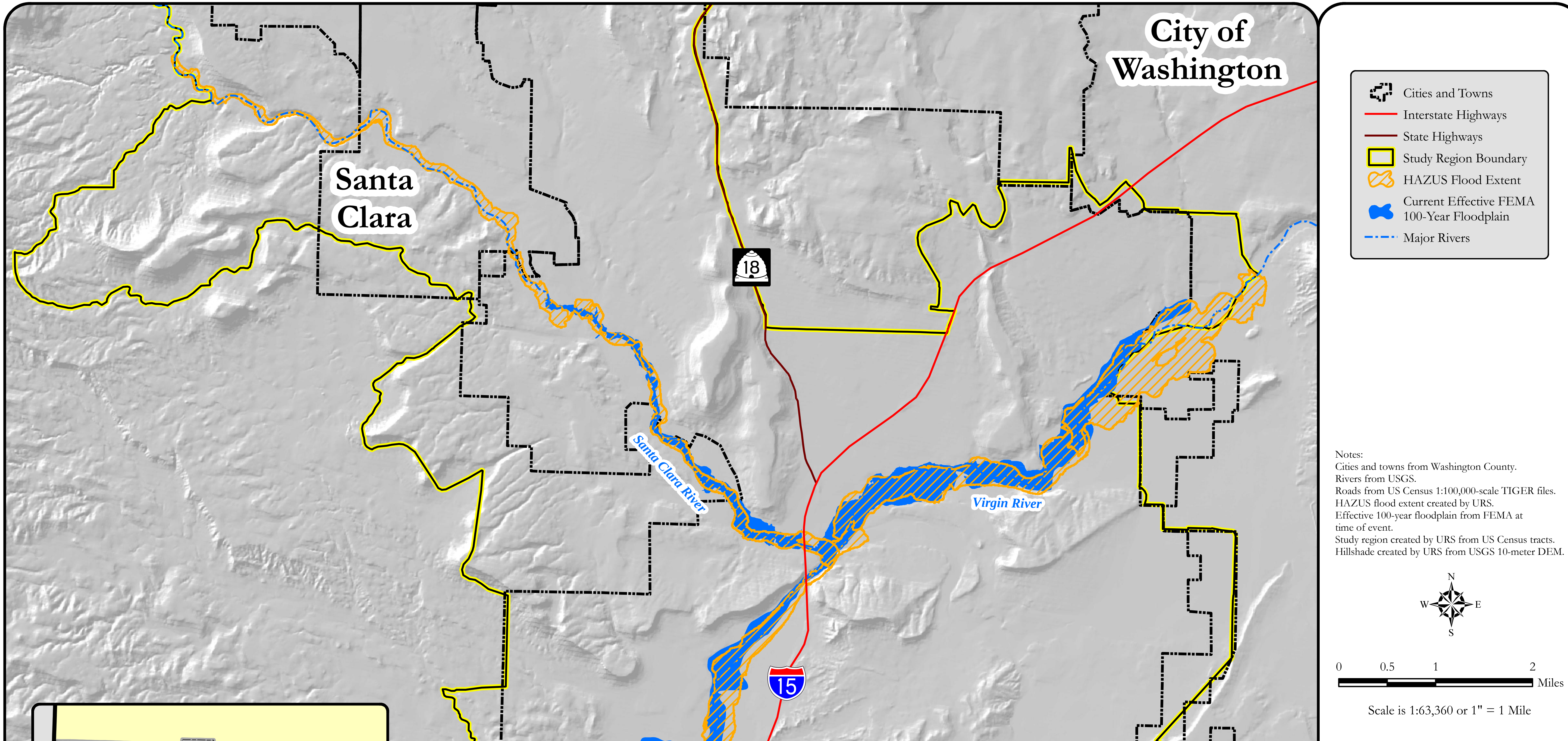


Figure 3.
HAZUS Results

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007

The Virgin River in the impact area is characterized by a deeply incised slot canyon and deep channel such as that in Zion National Park. As a result, the sampling density of the available 10-meter resolution DEM is not dense enough to define the steep slot canyon walls that contained the Virgin River floodwaters. Obviously a denser DEM could produce more accurate results, but another recommendation would be to review the pre-event aerial imagery, such as USGS digital orthophoto quarter quads, to confirm that the HAZUS flood extent boundary was reasonable.

Based on the slot canyon issues along the Virgin River and the lack of event damage, URS and FEMA decided to focus the remainder of the analyses on the lower Santa Clara River where available high water mark and damage location data were available. An approximately 3-mile-long segment of the Santa Clara River above the confluence with the Virgin River was chosen as a focused study area.

To better determine how HAZUS performed, URS obtained the flood boundary of the actual January 9-11, 2005 event. This permitted a three-way comparison between the modeled flood boundary, the effective FEMA 100-year floodplain, and the actual 2005 flood boundary. URS determined the flood boundary for the actual event by digitizing, directly on-screen, the extent of the flood from high-resolution aerial photographs taken on January 13, 2005 — 2 days after the event. Evidence of flooding, such as standing water, debris, damaged infrastructure, gullies, and channels in fields, were used to help determine the boundary.

GIS overlay analysis was later used to determine how HAZUS' flood boundary compared with the other flood boundaries. To accomplish this, the HAZUS-generated flood boundary was merged with the actual 2005 flood boundary and the area of overlap calculated. Alternatively, the HAZUS-generated flood boundary was also merged with the effective FEMA 100-year floodplain boundary and the area of overlap calculated.

3.3.2 Flood Elevation Comparison

Another validation of the HAZUS model is to compare it to actual elevations of floodwaters at specific locations. For this study, URS compared the HAZUS flood boundary elevations (based on the 10-meter DEM used by the model), the effective 100-year floodplain from FEMA, and the actual 2005 flood boundary.

Two sites within the Santa Clara River focus area were selected, and elevations from a 1-meter resolution Light Detection and Ranging (LIDAR)-based DEM were collected in cross sections to represent the channel shape. Before selecting each site, URS determined whether any changes to the channel had occurred between the January 2005 event and the May 2005 LIDAR flight. A combination of hillshading, aerial photographs, and elevation assessments were studied to confirm little or no channel improvements had occurred at each site.

At each site, a two-dimensional (2-D) line parallel to the channel was created in GIS and converted to a three-dimensional (3-D) line via the LIDAR-based DEM. This line represented the cross section of the channel. Next, the effective FEMA 100-year floodplain boundary, the actual 2005 flood boundary, and the HAZUS flood boundary were overlaid in GIS at each cross section. Points were then created where each flood boundary intersected the channel cross section. A point at the end of each cross section was also created. Elevations from the LIDAR-based DEM were then captured at each intersection point and cross section end. Elevations from the 10-meter resolution DEM were also captured where the HAZUS flood boundary intersected the cross section.

The 3-D cross section lines, as well as the flood boundary intersection points and associated elevations, were later converted to Autodesk's AutoCAD® software. URS then drew the cross sections, flood boundary intersection points, and cross section ends in profile to compare the water surface elevations of each flood boundary.

3.3.3 HAZUS Loss Comparison

One of the most powerful tools within HAZUS is the ability to calculate economic and social losses for specific events. HAZUS generated losses for many categories, as described in Section 3.2. However, because most damage was mainly limited to homes and bridges, URS and FEMA decided to focus this analysis on these losses. After further review of the GIS data made available to URS from FEMA and many local governments, it was decided that loss comparisons to homes would be the most useful because there were many ancillary GIS data sets that could help with the comparison.

The first step in the loss comparison analysis was to select the census blocks affected by the flood within HAZUS. A total of 24 census blocks were selected and mapped within the Santa Clara River focus area. Next, various loss statistics were calculated by HAZUS for each of the affected census blocks. These included the following:

- Estimated residential losses with no benefit from enrollment in the National Flood Insurance Program (NFIP). The NFIP uses FEMA Flood Insurance Rate Maps (FIRMs) for floodplain regulation, and once a community enrolls in the program it is required to elevate all new construction to at or above the base elevation for the 100-year flood.
- Total residential building replacement costs.
- The estimated number of residences that had damages exceeding 10% of the value of the structure.

In addition to the statistics calculated by HAZUS, URS gathered GIS data from the City of St. George showing the locations of damaged homes and data on home values from the Washington County Assessor's Office website. A list of these statistics is below:

- The total number of homes damaged per census block. These data were gathered from the City of St. George's GIS data and were confirmed by URS using aerial photographs. URS later located eight more damaged residences using the aerial photographs.
- The total number of homes in each census block. These counts were made from aerial photographs and compared to HAZUS structure counts by census block.
- Estimated losses for each damaged residence. Losses for each damaged residence were estimated from the Washington County Assessor's website. HAZUS estimates losses for structures and contents based on replacement cost, but not land surrounding structures (i.e., the entire parcel). Therefore, to make a proper comparison, URS gathered the April 2006 assessed value of each damaged residence's parcel (no assessed values were available from the county assessor for the residence only; rather the entire parcel with improvements had one value). The assessed value for the parcel was then multiplied by 77% to obtain the

assumed value of just the residence. This method is based on a report by the Washington County Assessor's Office that states that flood-damaged parcels lost about 77% of their overall value (Burton 2005). A copy of the Assessor's report is included in Appendix C. Once the assumed values were generated for each damaged residence, they were aggregated to the census block level.

After all of the statistics were compiled, a HAZUS residential loss ratio could be compared with an actual loss ratio based on the Assessor's data. By comparing the loss ratios rather than the actual value, the differences that could arise in comparing replacement costs and assessed valuations were alleviated.

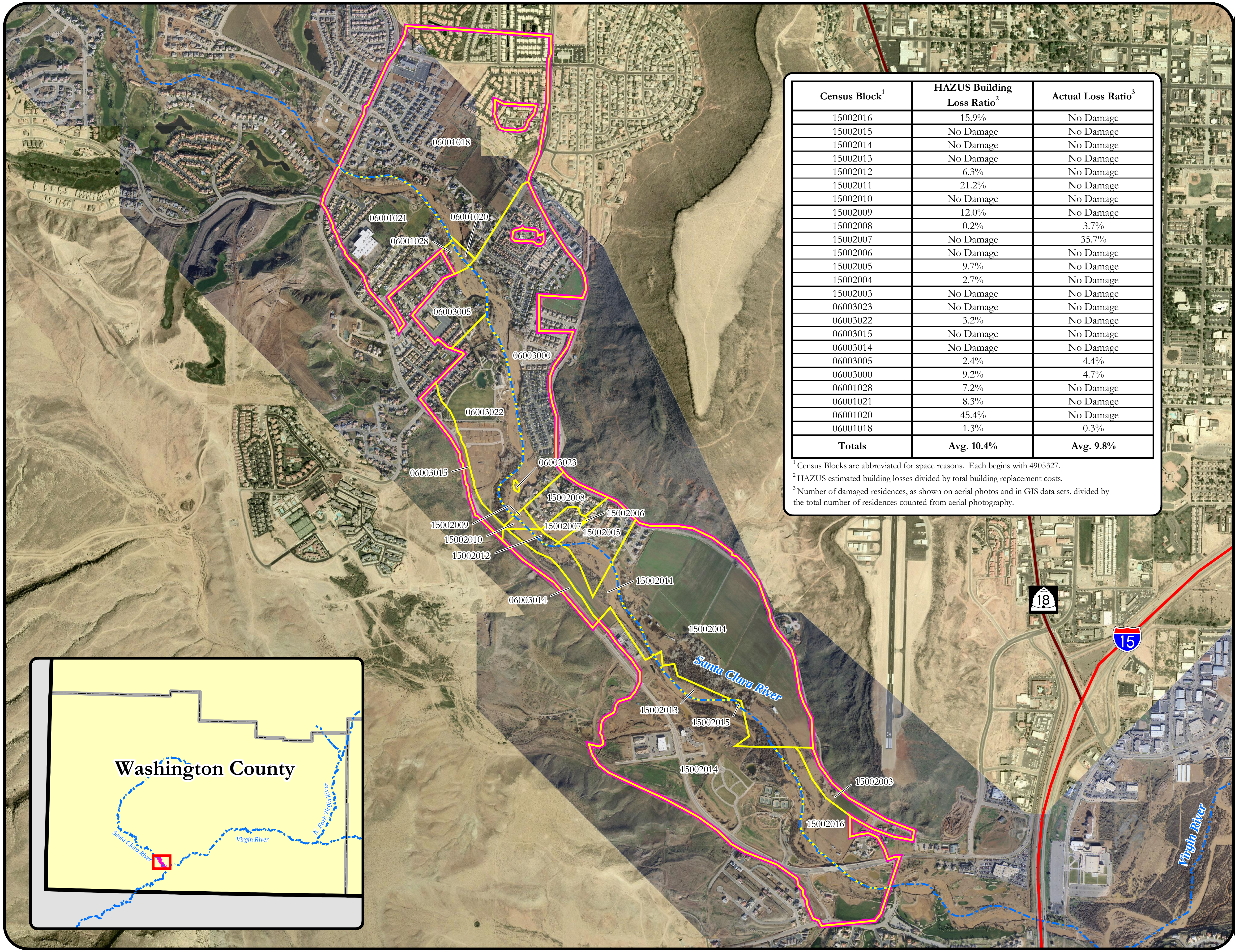
The results for the three analyses are shown in the following section. Figure 4 shows the lower Santa Clara River, the study locations for each of the analyses, and the census blocks that were used.

4.1 FLOOD BOUNDARY COMPARISON

Figures 5 and 6 show flood boundaries, census blocks, and the locations of the residences that were damaged by the flood. At many locations, the HAZUS flood boundary is similar to the actual 2005 flood boundary created using aerial photography. Although an exact match of modeled and actual flood boundaries would never be possible, HAZUS generally did a good job identifying which areas would likely flood. Census blocks 4905327- 06001028, 06001020, 06001018, 15002009, 15002005, 15002011, and 15002004 were modeled well, while the remainder of the study area was overestimated by HAZUS, resulting in a flood boundary that was too large. One likely cause of the flood boundary overestimation is because the DEM’s 10-meter elevation postings did not accurately interpret the narrow channel that is common along the Santa Clara River in that stretch. Another likely cause for the overestimation is the effects of debris, such as downed trees and bushes that were carried by the floodwaters. The debris blocked the channel in places and caused the flood water to pond behind the obstructions.

URS also compared the HAZUS flood boundary to the effective FEMA 100-year floodplain. In most areas, the 100-year floodplain was either similar in size or wider than the modeled flood boundary. Areas where the 100-year floodplain was wider typically were found in the upper and lower portions of the focus area, while areas that were similar in size generally occurred in middle sections. These observations are reasonable because the actual flood HAZUS modeled was estimated to be only a 22-year event. Therefore, the modeled flood boundary was not expected to be wider than the effective 100-year floodplain in most places. In sum, as can be seen in Figures 5 and 6, HAZUS did a better job estimating the actual 2005 flood boundary than did the effective FEMA 100-year flood boundary. This is logical because HAZUS was not used to model flows for a 100-year event — instead it modeled flows based on the actual 2005 event.

URS also conducted a GIS overlay analysis to compare the extents of each flood boundary. The HAZUS flood boundary captured a large majority of the actual 2005 flood boundary URS created from aerial photographs. Areas that do not overlap are found along the edges of the flood boundary throughout the length of the focus area. This exercise proves HAZUS can accurately estimate the boundary of an actual flood event where the DEM can sufficiently resolve the terrain. HAZUS is typically conservative in areas where steep channel walls that contain the flood event are not represented by the DEM.



Census Block[1]	HAZUS Building Loss Ratio[2]	Actual Loss Ratio[3]
15002016	15.9%	No Damage
15002015	No Damage	No Damage
15002014	No Damage	No Damage
15002013	No Damage	No Damage
15002012	6.3%	No Damage
15002011	21.2%	No Damage
15002010	No Damage	No Damage
15002009	12.0%	No Damage
15002008	0.2%	3.7%
15002007	No Damage	35.7%
15002006	No Damage	No Damage
15002005	9.7%	No Damage
15002004	2.7%	No Damage
15002003	No Damage	No Damage
06003023	No Damage	No Damage
06003022	3.2%	No Damage
06003015	No Damage	No Damage
06003014	No Damage	No Damage
06003005	2.4%	4.4%
06003000	9.2%	4.7%
06001028	7.2%	No Damage
06001021	8.3%	No Damage
06001020	45.4%	No Damage
06001018	1.3%	0.3%
Totals	**Avg. 10.4%**	**Avg. 9.8%**

[1] Census Blocks are abbreviated for space reasons. Each begins with 4905327.
[2] HAZUS estimated building losses divided by total building replacement costs.
[3] Number of damaged residences, as shown on aerial photos and in GIS data sets, divided by the total number of residences counted from aerial photography.

Santa Clara River Focus Area
Census Blocks and Numbers
Interstate Highways
State Highways
Major Rivers

Notes:
Census blocks from US Census.
Rivers from USGS.
Roads from US Census 1:100,000-scale TIGER files.
Focus area created by URS from US Census blocks.
1-meter regional aerial photo from USDA, flown in 2004.
0.5-meter river corridor aerial photo from FEMA, flown 1/13/05.

Census block numbers shortened for cartographic purposes. All numbers begin with 4905327.

N
W E
S

0 700 1,400 2,800 Feet

Scale is 1:16,800 or 1" = 1,400 Feet

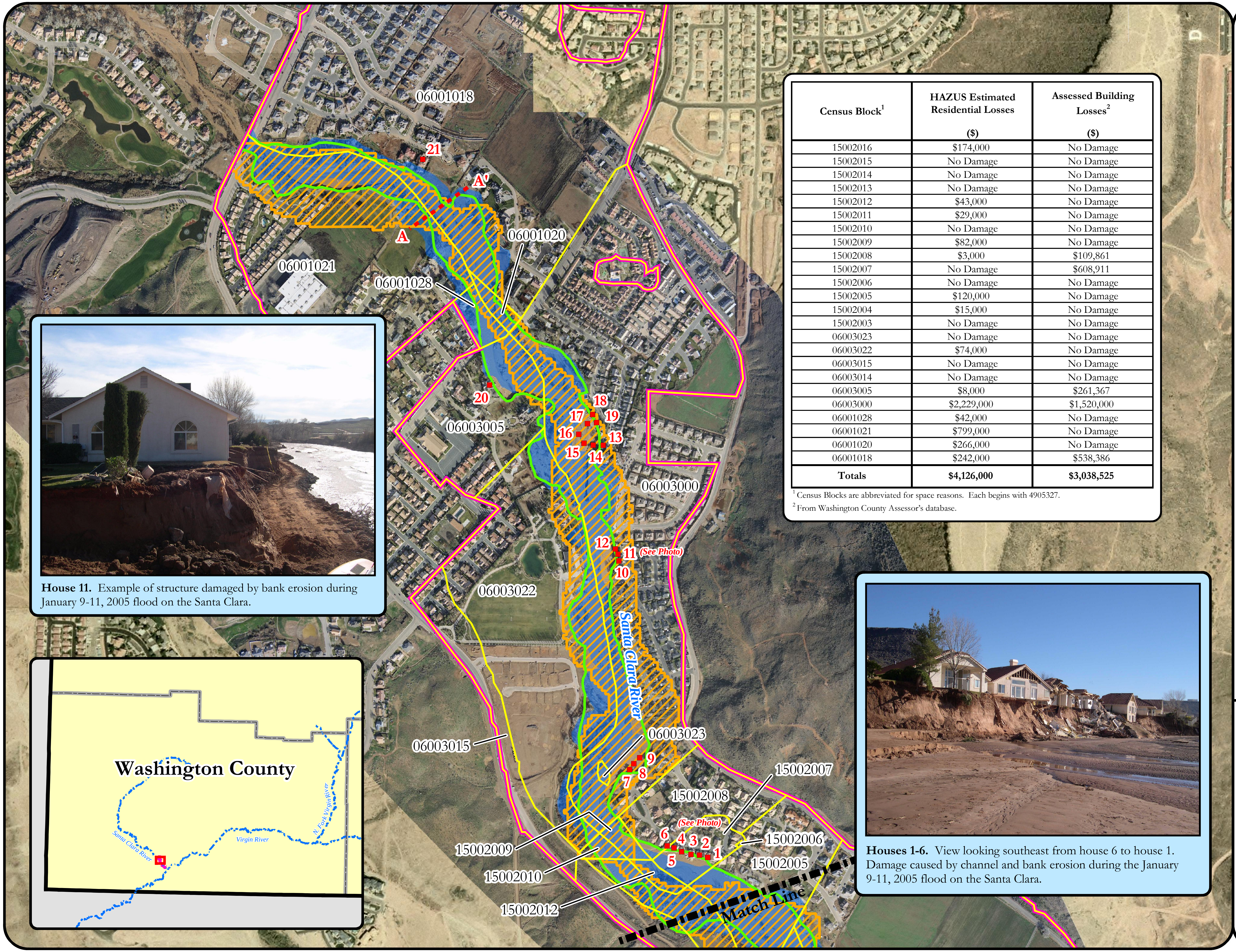
Figure 4. Santa Clara River Focus Area

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007



Census Block[1]	HAZUS Estimated Residential Losses ($)	Assessed Building Losses[2] ($)
15002016	$174,000	No Damage
15002015	No Damage	No Damage
15002014	No Damage	No Damage
15002013	No Damage	No Damage
15002012	$43,000	No Damage
15002011	$29,000	No Damage
15002010	No Damage	No Damage
15002009	$82,000	No Damage
15002008	$3,000	$109,861
15002007	No Damage	$608,911
15002006	No Damage	No Damage
15002005	$120,000	No Damage
15002004	$15,000	No Damage
15002003	No Damage	No Damage
06003023	No Damage	No Damage
06003022	$74,000	No Damage
06003015	No Damage	No Damage
06003014	No Damage	No Damage
06003005	$8,000	$261,367
06003000	$2,229,000	$1,520,000
06001028	$42,000	No Damage
06001021	$799,000	No Damage
06001020	$266,000	No Damage
06001018	$242,000	$538,386
Totals	**$4,126,000**	**$3,038,525**

[1] Census Blocks are abbreviated for space reasons. Each begins with 4905327.

[2] From Washington County Assessor's database.

House 11. Example of structure damaged by bank erosion during January 9-11, 2005 flood on the Santa Clara.

Houses 1-6. View looking southeast from house 6 to house 1. Damage caused by channel and bank erosion during the January 9-11, 2005 flood on the Santa Clara.

Santa Clara River Focus Area
Census Blocks and Numbers
Interstate Highways
State Highways
Current Effective FEMA 100-Year Floodplain
HAZUS Flood Extent
January 9-11, 2005 Flood Extent
Cross Sections
Homes damaged by January 9-11, 2005 Flood

Notes:
Census blocks from US Census.
Roads from US Census 1:100,000-scale TIGER files.
Focus area created by URS from US Census blocks.
January, 2005 flood extent created by URS from aerial photos.
Cross sections and HAZUS flood extent created by URS.
Current effective 100-year floodplain created by FEMA.
1-meter regional aerial photo from USDA, flown in 2004.
0.5-meter river corridor aerial photo from FEMA, flown 1/13/05.

Census block numbers shortened for cartographic purposes. All numbers begin with 4905327.

N W E S

0 350 700 1,400 Feet

Scale is 1:8,400 or 1" = 700 Feet

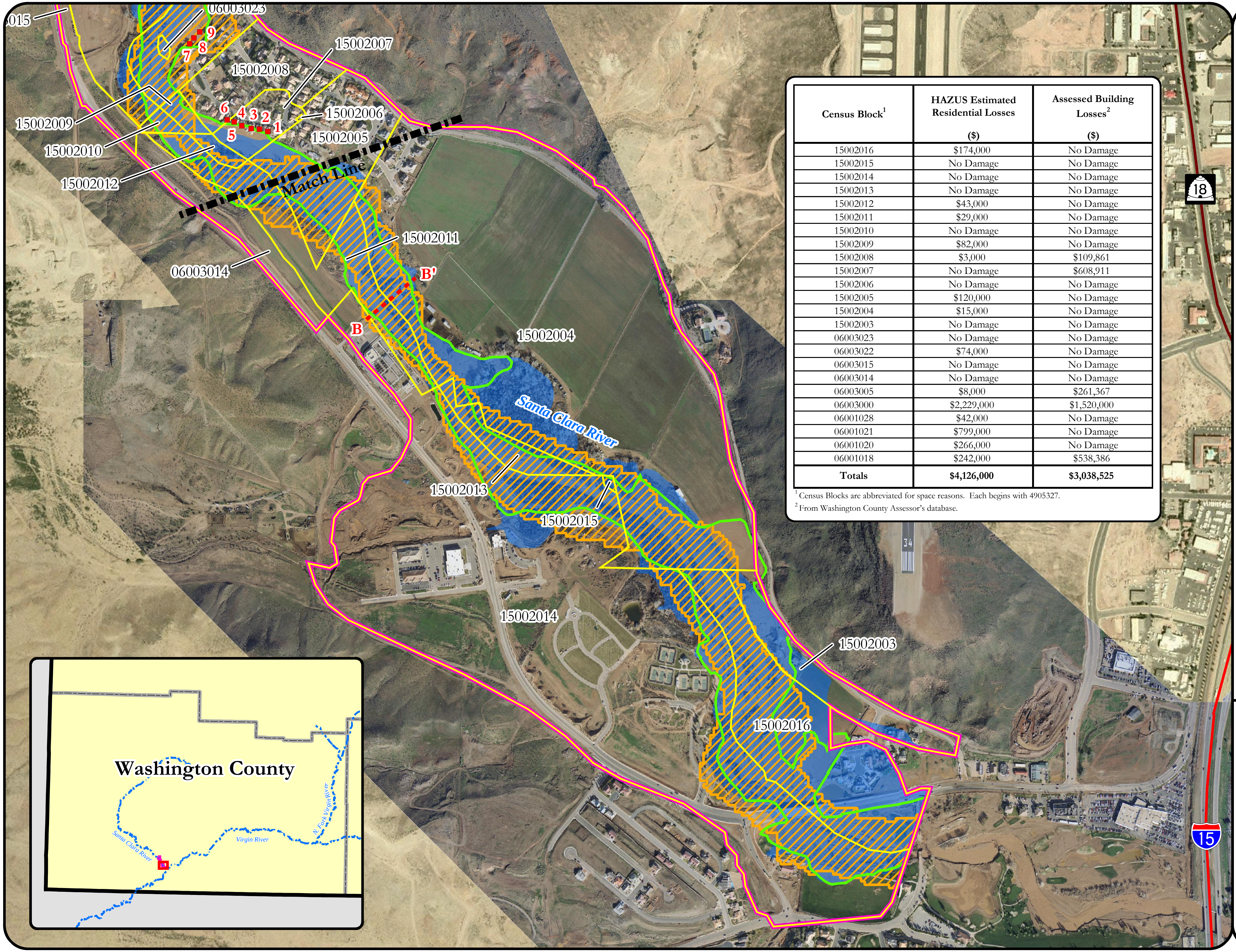
Figure 5. Flood Extent Comparison (North)

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007



Census Block[1]	HAZUS Estimated Residential Losses ($)	Assessed Building Losses[2] ($)
15002016	$174,000	No Damage
15002015	No Damage	No Damage
15002014	No Damage	No Damage
15002013	No Damage	No Damage
15002012	$43,000	No Damage
15002011	$29,000	No Damage
15002010	No Damage	No Damage
15002009	$82,000	No Damage
15002008	$3,000	$109,861
15002007	No Damage	$608,911
15002006	No Damage	No Damage
15002005	$120,000	No Damage
15002004	$15,000	No Damage
15002003	No Damage	No Damage
06003023	No Damage	No Damage
06003022	$74,000	No Damage
06003015	No Damage	No Damage
06003014	No Damage	No Damage
06003005	$8,000	$261,367
06003000	$2,229,000	$1,520,000
06001028	$42,000	No Damage
06001021	$799,000	No Damage
06001020	$266,000	No Damage
06001018	$242,000	$538,386
Totals	**$4,126,000**	**$3,038,525**

[1] Census Blocks are abbreviated for space reasons. Each begins with 4905327.
[2] From Washington County Assessor's database.

Santa Clara River Focus Area
Census Blocks and Numbers
Interstate Highways
State Highways
Current Effective FEMA 100-Year Floodplain
HAZUS Flood Extent
January 9-11, 2005 Flood Extent
Cross Sections
Homes damaged by January 9-11, 2005 Flood

Notes:
Census blocks from US Census.
Roads from US Census 1:100,000-scale TIGER files.
Focus area created by URS from US Census blocks.
January, 2005 flood extent created by URS from aerial photos.
Cross sections and HAZUS flood extent created by URS.
Current effective 100-year floodplain created by FEMA.
1-meter regional aerial photo from USDA, flown in 2004.
0.5-meter river corridor aerial photo from FEMA, flown 1/13/05.

Census block numbers shortened for cartographic purposes. All numbers begin with 4905327.

N
W E
S

0 350 700 1,400
Feet

Scale is 1:8,400 or 1" = 700 Feet

Figure 6. Flood Extent Comparison (South)

HAZUS-MH Riverine Flood Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

August 2007

4.2 FLOOD ELEVATION COMPARISON

Two cross sections were created along the Santa Clara River within the focus area. These cross sections represent the most critical areas for HAZUS to be able to run loss estimations for the validation study. That is, the areas most affected by the real event. Cross section A was placed just upstream of the Dixie Drive Bridge. Figure 7 shows the water surface elevations for this cross section. Cross section B was placed about 0.25 mile downstream of the Dixie Drive Bridge. Figure 8 shows the water surface elevations. At these cross-section locations, the HAZUS flood extent elevations are comparable with actual flood elevations and appear to be in better agreement with the actual flood surface than the 100-year Base Flood Elevations (BFEs) effective at the time of the flood.

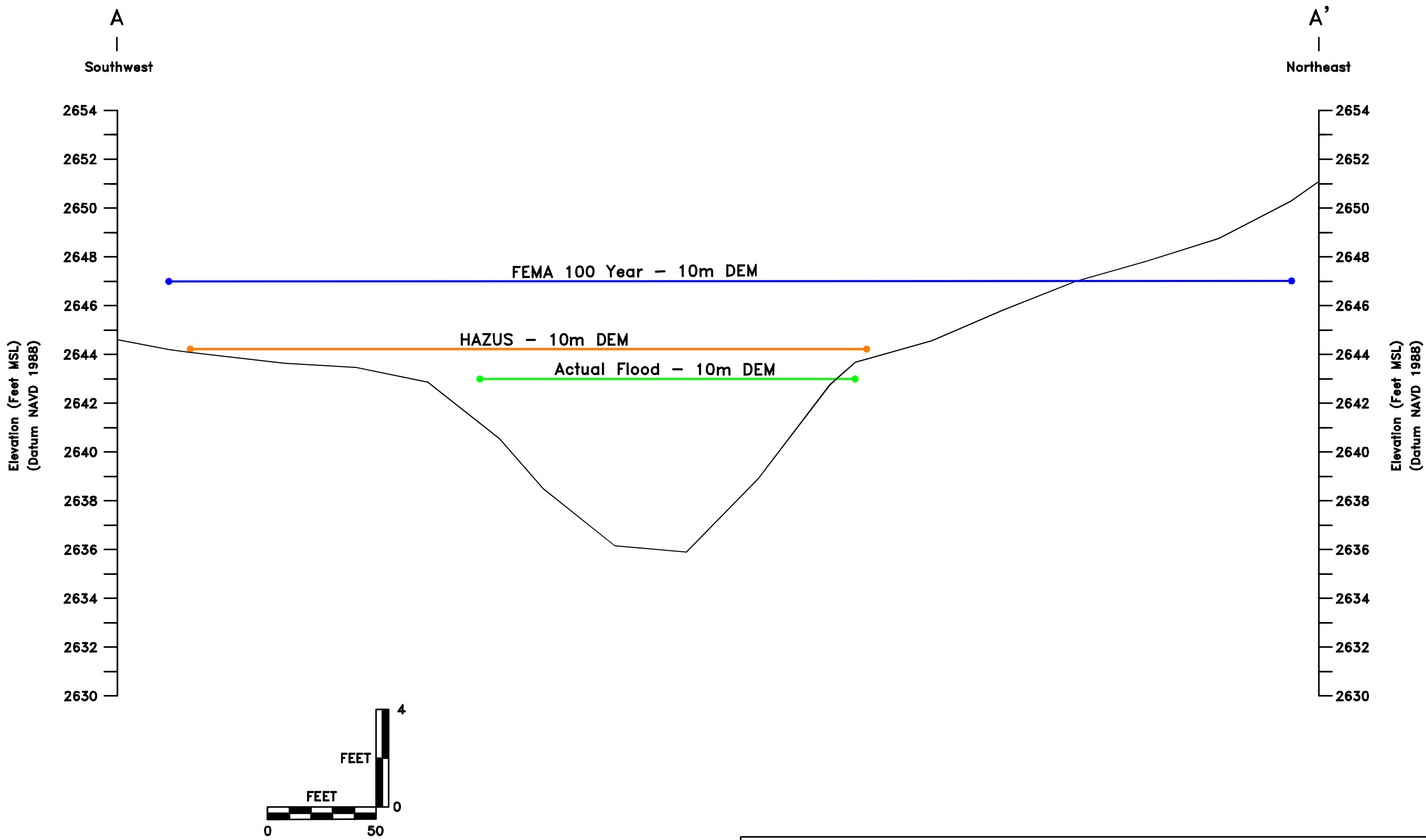
4.3 HAZUS LOSS COMPARISON

Table 1 compares the losses estimated by HAZUS with those generated using the Washington County Assessor's database. All estimates were aggregated to the census block level because HAZUS relies on this base GIS data for many components of its loss analyses. Overall, of the 24 census blocks included in the study area, 10 did not sustain any flooding as estimated by the HAZUS model run, mostly because the census blocks were located away from the river. These are noted as "No Damage" in the table. A quick visual assessment of Figures 5 and 6 shows that a total of 15 of the 21 damaged residences (71%) are located in census blocks that the model indicated had damages. The exception to this are the six residences located in census block 490532715002007. After further analysis of the flood boundaries and damage locations within GIS, URS determined the actual flood did affect these homes, but not by inundation. Instead, the damage was due to erosion from floodwaters eroding the channel and bank near these structures causing the bank to fail and slump into the river. The failure of the bank ultimately undermined the structures causing them to fall into the channel.

A comparison of the HAZUS residential losses ($4,126,000) to those from the county Assessor's data ($3,038,000) shows reasonable agreement. Another remarkable agreement was the 10.4% building loss ratio estimated by HAZUS, compared to the 9.8% actual loss ratio for the Santa Clara River focus area. However, there is significant disagreement within a few census blocks.

URS also compared how current enrollment in the NFIP helped reduce losses by dollar amount and number of damaged homes. HAZUS loss estimates show only two residences sustained damage to more than 10% of the home (each sustained damage to 10–20% of the home). However, an additional 58 residences sustained damage to less than 10% of the home.

Conversely, when HAZUS loss estimates were re-evaluated to account for the 1974 enrollment of St. George in the NFIP, total residential losses dropped by approximately 99% to $52,000 and no residences experienced damage from the modeled flood. These results illustrate the potential effectiveness of the NFIP, but since nearly all the damaged residences were outside the current effective 100-year floodplain, more accurate flood hazard mapping would be required for community enforcement of NFIP regulations.



HAZUS-MH Riverine Flood
Model Validation Study

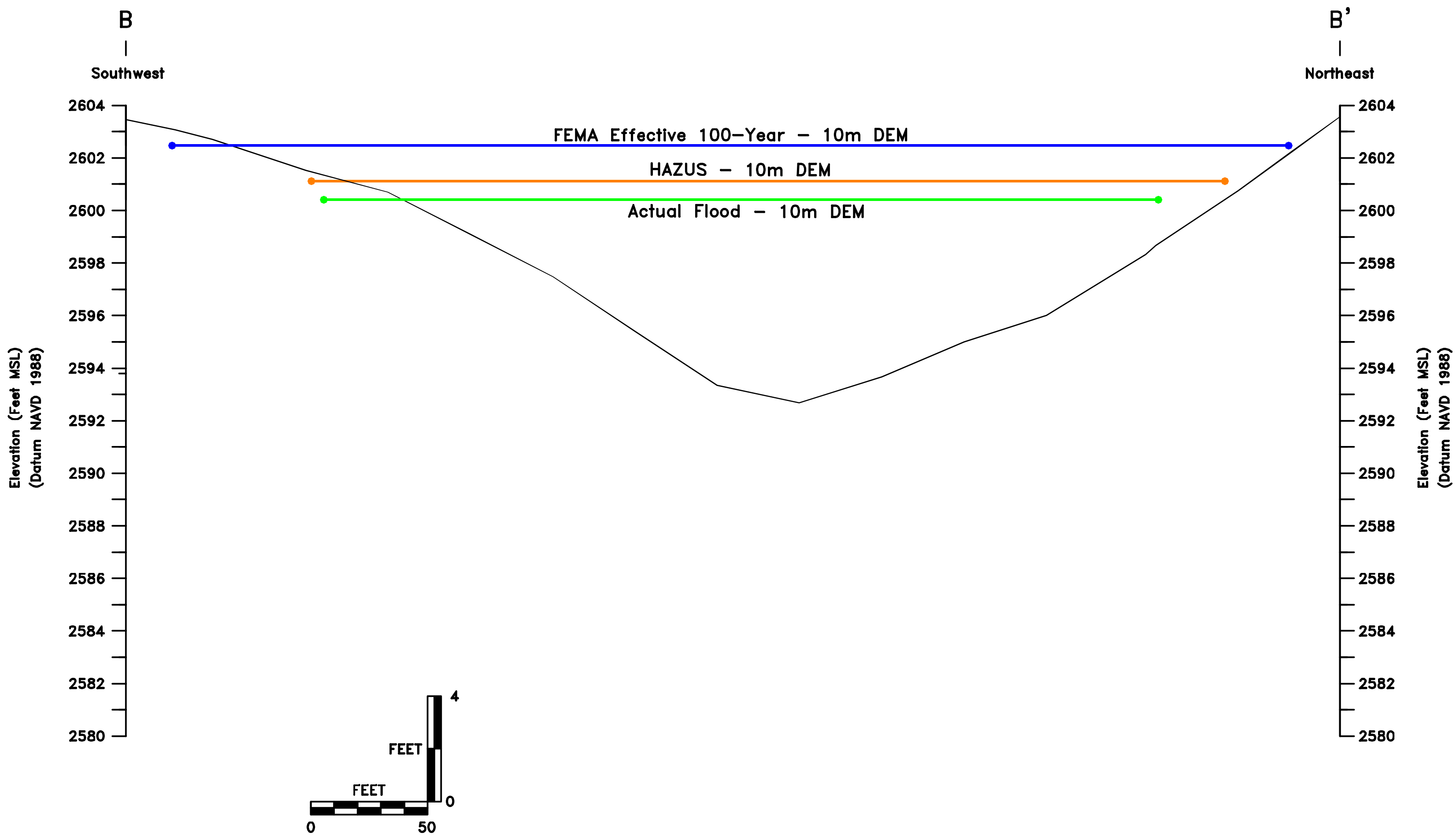
Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

Figure 7.

Flood Elevation Comparison - Cross Section A

August 2007



HAZUS-MH Riverine Flood
Model Validation Study

Washington County, UT Vicinity
Flood Disaster of January 9-11, 2005
Task Order 379

FEMA URS

Figure 8.
Flood Elevation Comparison - Cross Section B

August 2007

Table 1. Residential Loss Summary by Census Block

Census Block[1]	HAZUS Estimated Residential Losses ($)	Assessed Building Losses[2] ($)	HAZUS Residential Losses Counts[3] (> 10% Damage)	Actual Number of Damaged or Destroyed Homes[4]	HAZUS Building Loss Ratio[5]	Actual Loss Ratio[6]
15002016	$174,000	No Damage	0	0	15.9%	No Damage
15002015	No Damage	No Damage	0	0	No Damage	No Damage
15002014	No Damage	No Damage	0	0	No Damage	No Damage
15002013	No Damage	No Damage	0	0	No Damage	No Damage
15002012	$43,000	No Damage	0	0	6.3%	No Damage
15002011	$29,000	No Damage	0	0	21.2%	No Damage
15002010	No Damage	No Damage	0	0	No Damage	No Damage
15002009	$82,000	No Damage	0	0	12.0%	No Damage
15002008	$3,000	$109,861	0	1	0.2%	3.7%
15002007	No Damage	$608,911	0	5	No Damage	35.7%
15002006	No Damage	No Damage	0	0	No Damage	No Damage
15002005	$120,000	No Damage	0 *(2 houses < 10%)*	0	9.7%	No Damage
15002004	$15,000	No Damage	0	0	2.7%	No Damage
15002003	No Damage	No Damage	0	0	No Damage	No Damage
06003023	No Damage	No Damage	0	0	No Damage	No Damage
06003022	$74,000	No Damage	0 *(1 house < 10%)*	0	3.2%	No Damage
06003015	No Damage	No Damage	0	0	No Damage	No Damage
06003014	No Damage	No Damage	0	0	No Damage	No Damage
06003005	$8,000	$261,367	0	1	2.4%	4.4%
06003000	$2,229,000	$1,520,000	0 *(40 houses < 10%)*	13	9.2%	4.7%
06001028	$42,000	No Damage	0	0	7.2%	No Damage
06001021	$799,000	No Damage	0 *(14 houses < 10%)*	0	8.3%	No Damage
06001020	$266,000	No Damage	2	0	45.4%	No Damage
06001018	$242,000	$538,386	0	1	1.3%	0.30%
Totals	**$4,126,000**	**$3,038,525**	**2 homes > 10%; 58 homes < 10%**	**21**	**Avg. 10.4%**	**Avg. 9.8%**

Notes:
[1] Census blocks are abbreviated for space reasons. Each begins with 4905327.
[2] From Washington County Assessor's database.
[3] Residential counts without enrollment in the NFIP.
[4] Data collected via aerial photographs by URS or from GIS data provided by the City of St. George.
[5] HAZUS-estimated building losses divided by total building replacement costs.
[6] Number of damaged residences, as shown on aerial photographs and in GIS data sets provided by the City of St. George, divided by the total number of residences counted from aerial photographs.

Loss ratios developed from HAZUS and the county Assessors' data can also be compared. The last two columns of Table 1 show the HAZUS building loss ratio and the actual loss ratio per the Assessors' data. The HAZUS percent loss ratio was calculated by dividing the HAZUS estimated building losses (without NFIP) by the total building replacement costs. The totals were then averaged and came to an average HAZUS loss ratio of 10%. Similarly, the actual loss ratio based on the Assessor's data was calculated by dividing the number of damaged residences (as shown on the aerial photographs and in GIS data sets provided by the City of St. George) by the total number of residences on the aerial photographs. The actual loss ratio also averaged 10%. The two average loss ratios equaled each other despite being calculated from very different sources. This is because the HAZUS loss ratio was calculated from statistics that, although stated in dollars, really indicate the number of residences damaged, just like the ratio calculated from the Assessor's data. Table 1 also shows that not all census blocks have both ratios calculated. This is explained by the source of the statistics. For instance, according to HAZUS, census block 490532715002005 has $120,000 in estimated losses, but the actual flood did not cause any damage to homes in that census block (for a ratio of zero). So, although ratios cannot always be compared by census block, a more general comparison can be made if ratios are averaged over an entire study area.

URS and FEMA also decided to color-code Table 1 to indicate which census blocks had HAZUS loss ratios that were similar to or different from the actual loss ratios. This comparison was conducted by taking the difference between the HAZUS-estimated losses without the benefit of the NFIP and the assessed building losses per the Assessor's database and dividing by the average of the same two statistics. The green census blocks are those that compared well (0–40% difference). Blue census blocks (40%–80% difference) and red census blocks (greater than 80% difference) are those that compared more poorly.

Table 1 indicates most of the green census blocks compared well because HAZUS agreed that no residential damages occurred as indicated by the Assessor's database. The lone exception is census block 490532706003000 where HAZUS losses are within about 38% of assessed building losses. A closer look at the census blocks that compared poorly (colored blue or red) shows that of the 13 census blocks, 10 compared poorly because no actual residences were damaged; however, HAZUS estimated damages to at least some residences in each of these census blocks. This discrepancy is likely caused by HAZUS' overestimation of the flood depth and extent in certain locations. As a result, the modeled flood affects a larger area and causes more residential damage when compared to the actual Assessor's damages. This comparative analysis offers better results when total HAZUS and assessed building losses are used. Comparing these statistics indicates total HAZUS losses are within about 30% of total assessed building losses. In sum, while HAZUS and assessed building losses may not compare well for individual census blocks, totaling the losses for the entire focus area provides a more accurate comparison. Clearly, enhancement to the Level I inventory with site-specific information would be required for HAZUS to provide reasonable results at individual census blocks or at individual sites.

Lastly, actual total building economic losses for the entire event, estimated by FEMA based on the NWS flood forecast prior to the peak flows, were approximately $25 million. These updated HAZUS results, based on this analysis, estimated the same losses to be about $31 million, which are in reasonable agreement with the NWS flood warning estimate. Much of the general overestimate is likely related to the assumption of equal distribution of the building stock throughout the census block. Typically, the built environment in census blocks that intersect a floodplain would be concentrated in areas of the census block away from floodways or floodplains. Perhaps an enhancement is needed to the area-weighting calculations, but for emergency management purposes, it may be better for HAZUS to provide conservative loss estimations.

This section summarizes the major conclusions of this study and determines whether HAZUS is a suitable tool to estimate flood damages prior to, during, and after floods.

- Flood boundaries modeled by HAZUS generally estimate actual flood boundaries quite well. However, the estimate of flood boundaries and depth grids are highly dependent on the resolution of the digital terrain data.
- HAZUS cannot accurately model floods that occur in narrow canyons as demonstrated by the overestimation of the modeled flood boundary along the Virgin River upstream of the confluence with the Santa Clara River. A more accurate elevation surface with better resolution, perhaps using LIDAR technology and/or a user-supplied depth grid, could fix this problem.
- Along the Santa Clara River, the HAZUS flood extent elevations are comparable with actual flood extent elevations and appear to be in better agreement with the actual flood surface than the 100-year BFEs effective at the time of the flood.
- HAZUS residential losses along short reaches of flooded rivers are comparable with true residential losses. However, HAZUS losses are still only estimates, so particular categories will vary from true losses, especially when looking at an individual site with only Level I data.
- Building losses due to erosion and undermining of highly erodible soils require editing of the default depth-damage curves in HAZUS to represent significant losses from relatively shallow flood events.
- Average percent building loss ratios generated by HAZUS are comparable to those estimated using actual Assessor’s market value data. Comparisons of loss ratios help remove uncertainty caused by different building valuation methodologies.
- Total HAZUS residential losses are approximately 30% higher than the total assessed residential losses. Comparing total losses for a study reach is more accurate than comparing total losses at individual census blocks. Overall, the census block area-weighting loss estimation approach is likely conservative since buildings in each census block are likely concentrated in areas outside areas subject to potential flooding.
- HAZUS loss estimates, when re-evaluated to account for the 1974 enrollment of St. George in the NFIP, resulted in minimal modeled residential losses ($52,000 vs. $4,126,000). These results illustrate the potential effectiveness of the NFIP, but would have required a more accurate flood hazard map for enforcement of NFIP regulations since nearly every damaged residence was outside the effective 100-year flood zone.

HAZUS is a very useful tool to help model flood boundaries and estimate economic and social losses. Provided accurate event flow discharges are available through accurate forecasting, at gages or other known locations along the reach of interest, HAZUS can help provide timely flood boundary and loss-estimate information before, during, or after a flood.

Burton, J. 2005. *Special Study on Erosion Hazard Boundary St. George Utah.* Washington County Assessor's Office.

Smart, C. and M. Havnes. 2006. S. Utah Flood Victims Rebuild Homes and Lives. *The Salt Lake Tribune*, January 9, sec. A.

US Census Bureau. 2006. *State & County QuickFacts*. [Online] Available: http://quickfacts.census.gov/qfd/states/49/49053.html.

United States Geological Survey (USGS). 2006. *Flood in Virgin River basin, Southwestern Utah, January 9-11, 2005*. [Online] Available: http://ut.water.usgs.gov/FLOODING/Virgin_flood.html.

Appendix A

NWS Flood Advisory

FLOOD WARNING

AZC015-UTC053-120000-

FLOOD STATEMENT...CORRECTED EXPIRATION CODE
NATIONAL WEATHER SERVICE SALT LAKE CITY UT
1235 PM MST TUE JAN 11 2005

...FLOOD WARNING REMAINS IN EFFECT UNTIL 6 AM MST WEDNESDAY FOR THE RIVERS AND STREAMS IN WASHINGTON COUNTY AND THE VIRGIN RIVER FROM ZION NATIONAL PARK THROUGH MOHAVE COUNTY TO THE NEVADA STATE LINE.

HEAVY RAINFALL ACROSS WASHINGTON COUNTY CONTINUES TO FUEL ALREADY SWOLLEN RIVERS AND STREAMS. REPORTS OF DAMAGE TO HOMES...ROADS...AND BRIDGES IS WIDESPREAD ACROSS THE SANTA CLARA AND VIRGIN RIVER DRAINAGES.

RIVER FORECASTS CALL FOR THE SANTA CLARA TO REACH 7000 CFS AT 3 PM MST TUESDAY. THIS FLOW IS A FLOW OF RECORD FOR THE SANTA CLARA AT ST. GEORGE.

THE VIRGIN RIVER NEAR HURRICANE IS FORECAST TO FLOW AT 11600 CFS. MONDAYS FLOWS REACHED 10000 CFS. THE TIME OF PEAK IS EXPECTED AT 5 PM MST TUESDAY.

A COLD FRONT WILL MOVE ACROSS THE AREA THIS AFTERNOON USHERING IN COLDER AIR...WITH SNOW LEVELS LOWERING TO AROUND 6000 FT. PRECIPITATION BENEATH THIS ELEVATION WILL BE IN THE FORM OF RAIN...POSSIBLY MIXED WITH SNOW AT TIMES. WITH THE ABSENCE OF RAINFALL AT THE HIGHER ELEVATIONS...RIVERS AND STREAMS WILL REDUCE THEIR FLOW AND BEGIN TO DECLINE.

ALL RIVERS AND STREAMS WILL EXPERIENCE REDUCED FLOWS BY MIDNIGHT WEDNESDAY MORNING.

THESE WATERWAYS ARE EXTREMELY DANGEROUS. DO NOT ATTEMPT TO DRIVE THROUGH ANY FLOODED INTERSECTIONS...OR FLOODED ROADWAYS.

$$

MCINERNEY

Appendix B

USGS Flood Discharge Summary

USGS

Flood in Virgin River basin, Southwestern Utah, January 9-11, 2005

Estimates of instantaneous peak discharges at U.S. Geological Survey (USGS) streamflow-gaging stations for the Virgin River Basin flood of January 9-11, 2005, are provided below. Recurrence interval discharge estimates were computed for each streamflow-gaging station by using two techniques. Estimates were obtained by applying developed regional regression models (Thomas and others, 1997), and by conducting a flood-frequency analysis of the gaging-station record following the guidelines outlined in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The Four Corners Region 8 (Thomas and others, 1997) regression equations that were used are provided below. In an effort to reduce time-sampling error in the station flood-frequency estimates, weighted recurrence interval estimates also are presented. A graph showing the period of annual peak record analyzed for each station plotted along with the the annual peak discharges for the Virgin River near Virgin, Utah, through water year 2004, are shown below. A list of references for the techniques employed is also provided. All data presented is provisional and is subject to revision. Some peak discharges revised March 21, 2006.

Table of provisional estimates of peak discharges at USGS streamflow-gaging stations for the January 9-11, 2005, flood in the Virgin River basin in southwestern Utah

Station number	Station name	Drainage area (square miles)	Mean basin elevation (feet, NGVD 1929)	Years of peak record used in analysis	Peak discharge from flood (cubic feet per second)	Gage height (feet)	Remarks
09404450	East Fork Virgin River near Glendale, Utah	69	7,300	37	405	3.92	
09404900	East Fork Virgin River near Springdale, Utah	343	6,323	13	3,530	11.91	From floodmark and rating curve extended above 233 cfs on basis of slope-area measurement at gage height 9.70 ft.
09405500	North Fork Virgin River near Springdale, Utah	344	7,350	81	5,450	9.18	
09406000	Virgin River near Virgin, Utah	934	6,400	88	9,840	17.69	Peak discharge determined by extending stage/discharge rating more than twice the largest measured discharge.
09408000	Leeds Creek near Leeds, Utah	16	6,360	41	2,230	7.67	
09408150	Virgin River near Hurricane, Utah	1,499	6,350	18	21,000	19.36	

09408195	Fort Pearce Wash near St. George, Utah	1,349	5,119	8	440	5.58	GH from HWM
09408400	Santa Clara River near Pine Valley, Utah	19	8,720	45	84	2.76	No significant flows from this portion of Santa Clara River basin. Peak was on 10-20-04 (988 cfs), WY 2005.
09409100	Santa Clara River abv Baker Reservoir, near Central, Utah	116	7,398	15	440	3.64	Peak of WY 2005 was on 10-21-04, 1700 cfs (est), GH = 6.80 ft.
09409880	Santa Clara River at Gunlock, Utah	271	6,224	35	5,200	10.21	Peak discharge determined from stage discharge rating developed by USGS in 1993 for flow over Gunlock Reservoir spillway. Discharge into Gunlock Reservoir at peak assumed to be equal to flow over spillway.
09413000	Santa Clara River at St. George, Utah	541	5,260	26	6,200	16.68	Peak discharge determined for flow over a broad crested weir 0.5 mile downstream. Computations of flow through Mathis Bridge used as controls for weir computation.
09413200	Virgin River near Bloomington, Utah	3,853	5,409	18	19,600	26.66	
09413500	Virgin River near St. George, Utah	4,123	5,347	13	19,600	22.13	
09413900	Beaver Dam Wash near Enterprise, Utah	58	5,951	13	1,360	13.91	Peak discharge determined on basis of slope-area computation.

Table of recurrence interval discharge estimates for USGS streamflow-gaging stations in the Virgin River basin in southwestern Utah through water year 2004

Peak discharge estimates (cubic feet per second) for indicated recurrence interval (years) and method of computation			
		Analysis of gage record following Bulletin	

Station Number	Application of region 8 regression equations 2	5	10	25	50	100	17B 2	5	10	25	50	100	Weighted estimate 2	5	10	25	50	100
09404450	660	1,380	1,990	3,000	3,910	4,880	96	220	346	569	791	1,070	98	234	392	704	1,030	1,450
09404900	1,700	3,400	4,800	7,070	9,110	11,200	778	2,110	3,490	5,870	8,160	10,900	795	2,210	3,700	6,200	8,490	11,000
09405500	1,460	2,810	3,890	5,660	7,230	8,840	1,690	3,110	4,240	5,840	7,160	8,570	1,690	3,100	4,220	5,830	7,170	8,600
09406000	2,770	5,250	7,230	10,400	13,200	16,000	3,640	6,770	9,420	13,500	17,000	21,000	3,630	6,740	9,350	13,300	16,700	20,500
09408000	358	840	1,280	2,010	2,700	3,460	151	665	1,450	3,330	5,710	9,280	152	670	1,440	3,140	5,090	7,730
09408150(1)(2)	3,540	6,560	8,930	12,700	16,100	19,400	3,890	6,140	7,620	9,430	10,700	12,000	3,880	6,170	7,790	10,100	12,100	14,100
09408195	4,180	8,240	11,500	16,800	21,500	26,300	1,250	3,790	6,940	13,500	20,900	31,200	1,310	4,240	7,940	14,700	21,200	28,500
09408400	285	610	889	1,360	1,790	2,250	66	161	238	390	542	732	67	168	257	446	642	887
09409100	840	1,710	2,430	3,620	4,690	5,810	63	207	399	825	1,340	2,090	67	246	534	1,220	2,030	3,090
09409880(1)	1,530	3,120	4,440	6,580	8,510	10,500	315	971	1,750	3,270	4,910	7,070	320	1,010	1,880	3,600	5,410	7,680
09413000(1)	2,570	5,280	7,540	11,200	14,400	17,800	628	1,880	3,280	5,840	8,420	11,600	640	1,980	3,560	6,540	9,490	13,000
09413200(1)(2)(3)	6,690	12,300	16,700	23,700	29,800	35,800	3,540	5,800	7,400	9,490	11,100	12,700	3,590	6,120	8,280	11,700	14,800	18,000
09413500(1)(2)(3)	7,000	12,900	17,500	24,700	31,100	37,400	2,530	3,990	5,150	6,840	8,270	9,850	2,600	4,460	6,430	10,000	13,400	17,200
09413900 (4)	741	1,650	2,460	3,780	5,000	6,320	243	1,200	2,590	5,590	8,940	13,400	251	1,240	2,560	4,980	7,240	9,810

1. Discharge currently affected by regulation or diversion, only peaks occurring since regulation were analyzed.
2. Annual peaks associated with dam failure were not used in analysis.
3. Drainage area greater than 2,000 square miles; regional regression dataset did not include drainage areas greater than 2,000 square miles.
4. Station located within Northern Great Basin Region 6, however, regression analysis was conducted using Four Corners Region 8 equations based upon more representative hydrologic, climatic, and drainage basin characteristics.

Table of generalized least-squares regression equations for estimating regional flood-frequency relations for the Four Corners Region 8

[Equation: Q, peak discharge, in cubic feet per second; AREA, drainage area, in square miles; and ELEV, mean basin elevation, in feet, NGVD 1929]

Region 8 -108 stations		
Region equation	**Average standard error of prediction, in percent**	**Equivalent years of record**
$Q2 = 598\ AREA^{0.501}\ (ELEV/1{,}000)^{-1.02}$	72	.037

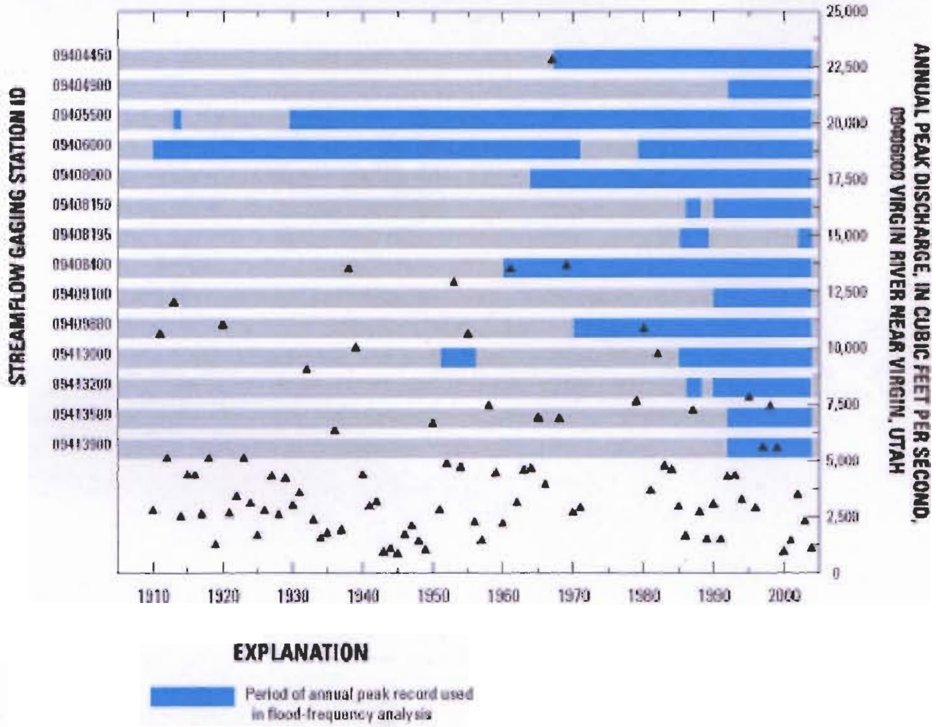
$Q_5 = 2{,}620\ AREA^{0.449}\ (ELEV/1{,}000)^{-1.28}$	62	1.35
$Q_{10} = 5{,}310\ AREA^{0.425}\ (ELEV/1{,}000)^{-1.40}$	57	2.88
$Q_{25} = 10{,}500\ AREA^{0.403}\ (ELEV/1{,}000)^{-1.49}$	54	5.45
$Q_{50} = 16{,}000\ AREA^{0.390}\ (ELEV/1{,}000)^{-1.54}$	53	7.45
$Q_{100} = 23{,}300\ AREA^{0.377}\ (ELEV/1{,}000)^{-1.59}$	53	9.28

Equation used in weighted estimates:

$$\log Q_T(W) = \frac{N \cdot \log Q_T(G) + EQ \cdot \log Q_T(R)}{N + EQ}$$

where:

$Q_T(W)$	is the weighted estimate for recurrence interval T at the gaged site, in cubic feet per second
$Q_T(G)$	is the estimate derived from analysis of the gage records, in cubic feet per second
$Q_T(R)$	is the estimate of Q T derived from application of the regression equation, in cubic feet per second
N	is the number of years of stream gage record, and
EQ	is the equivalent years of record (table 1 and 2).



Selected References

Interagency Advisory Committee on Water Data, 1982, Guidelines for determining flood frequency: Washington, D.C., Interagency Advisory Committee on Water Data, Hydrology Subcommitteee Bulletin 17B, 193 p.

Perl, C.D., and Ries, K.G., III, 2002, The National Flood Frequency Program, Version 3: U.S. Geological Survey Fact Sheet 084-02, p. 4

Ries, K.G., III, and Crouse, M.Y., 2002, The National Flood Frequency Program, Version 3: A Computer Program for Estimating Magnitude and Frequency of Floods for Ungaged Sites, 2002: U.S. Geological Surve Water-Resources Investigations Report 02-4168, 42 p.

Thomas, B.E., Hjalmarson, H.W., and Waltemeyer, S.D., 1997, Methods for estimating magnitude and frequency of floods in the southwestern United States: U.S. Geological Survey Water-Supply Paper 24333, 195 p.

URL:http://ut.water.usgs.gov /FLOODING/Virgin_flood.html
return to Utah home page

U.S. Department of the Interior
U.S. Geological Survey
2329 Orton Circle, West Valley City, Ut, 84119
Maintainer: GS-W-UT_Web_Requests@usgs.gov
Last Modified: Tuesday, 21-Mar-2006 18:00:10 EST Privacy Statement || Disclaimer||Accessibility

Appendix C

Washington County, UT Assessor's Report

SPECIAL STUDY

ON

Erosion Hazard Boundary
St. George, Utah

FOR

FEMA

Report Date: July 12, 2005

by
Judith Burton
Certified Residential Appraiser
Washington County
Assessor's Office

RECEIVED
JUL 25 2005

July 13, 2005

Mike Hillenburg, *Civil Engineer*
Scott Roscoe, *Mitigation Specialist*
DHS, FEMA Region VIII
Bldg. 710A, DFC
Denver, CO 80225

Dear Gentlemen,

Pursuant to your request, I have inspected the parcels located along the Santa Clara River from the Santa Clara City boundary southeast to the confluence with the Virgin River and proceeding southwest along the Virgin River from the confluence to the St. George City limits. This study was conducted for the purpose of estimating the amount of additional damage dollars that could have been lost were it not for the adoption and enforcement of the St. George Erosion Hazard Boundary Ordinance.

I have estimated the value of the unimproved parcels located within the Erosion Hazard Boundary, but outside the FEMA Flood Line, at its Highest and Best Use as though improved at the time of the flood. In order to simplify the study, I have broken the area in question into 3 separate areas or Study Maps. These maps consist of the following: 1) Santa Clara River from Santa Clara City limits to Valley View Drive; 2) Valley View Drive to I-15 and the confluence with the Virgin River; 3) The confluence southwest along the Virgin River through Bloomington and Sun River to the St. George City limits. Each map along with its findings and assumptions are reviewed separately within this report. These findings and assumptions are then reconciled and compiled into a final estimate of damage dollars saved.

Because of the nature of this report, many hypothetical assumptions and determinations were required on the part of the appraiser. Review and analysis of existing, improved subdivisions along the Erosion Hazard Boundary were used to help establish estimates of potential development on the unimproved parcels. The valuation assumptions are based on current market data taken from sales of properties within each study area and information collected from the Assessor's office. Where insufficient market data was available, the cost approach was used to assist in the valuation process. A more complete description of the study areas, together with sources of information and basis of estimates are located in the appraiser's work files.

The estimates of value herein are intended solely for your information and use in the management of environmentally sensitive lands.

Respectfully submitted,

Judith Burton

Judith Burton
Certified Residential Appraiser
#CR00051798

Study Area 1 - Santa Clara River from Santa Clara City Limits to Valley View Drive, St. George.

The majority of the land within this study area was fully developed prior to the 2005 Flood. Sun Brook Golf Course, Mathis Park and City trails occupy a large portion of the flood way. A total of 58 improved lots and 18 unimproved lots have river frontage with at least the rear yards within the Erosion Hazard Area. Other than damage estimated at $48,166 to the rear yard of the home located at 1574 Brook View, just west of the Valley View Bridge, no other loss of value was reported in this area.

Three parcels of farm land with a potential for residential development still exist north of the river on the western edge of the Study Area. It is estimated that an additional 15 lots could be developed along the river, however, it is likely all would be outside the Erosion Hazard Boundary.

The only other vacant parcel in this area that lies within the Erosion Hazard Boundary is a small, irregular shaped commercial parcel of .91 acres on Dixie Drive south of the river. This parcel adjoins an additional .76 acres for a total 1.67 acres of commercial land. With this much acreage there is plenty of room for an improvement outside of the hazard zone and presents little potential for additional revenue loss.

It is estimated that no additional dollars would be lost in this Study Area had the available vacant lands been developed.

Study Area 2 - Santa Clara River from Valley View Drive to I-15

This area sustained the greatest amount of loss from the recent flooding. It also has the greatest availability of land along the Santa Clara River for potential development. There are a total of 72 improved parcels with river frontage in this area. Of these 72 parcels, 24 parcels were reported to the Assessor's Office as either destroyed or damaged during the flooding. This represents 33% of the parcels. The total value of the damaged parcels prior to the flood was $4,443,307. According to Assessor's Office calculations, these parcels sustained a loss in value of $3,441,278 or approximately 77% For the purpose of this report, these percentages were used for the calculation of the estimated potential of additional dollars lost.

Given approximately 4,200 feet of river frontage on the Gubler farm and an additional 700 feet in the proposed future phases of the Olive Grove Subdivision, I have estimated the potential for 50 additional residential river front lots. Analysis of existing developments indicates that of these 50 lots 90% would be fully built out. Based on current market information, it is estimated that these parcels, when improved, would have an average value of $250,000 for a total estimated value of $11,250,000 (45 X 250,000). The total value of the 5 vacant parcels is estimated at $300,000 ($60,000 X 5) for a total value of $11,550,000. Using the percentages from the paragraph above, if only 33% of the parcels were damaged or destroyed and they sustained a loss in value of 77% this would indicate a potential additional loss in residential properties of $2,934,855.

This area also contains approximately 29 acres of useable commercially zoned river front land within the Environmental Hazard Boundary. Currently, there are only two improvements within the boundary, the Plant World building and Building 1 of the Tonaquint Office Condo development. The Assessor's office shows the land value of this 29 acres at $2,726,806. Existing improvements are valued at $1,943,020. For the purpose of this report, the appraiser has estimated the potential for additional improvements value at approximately $3,500,000. This brings the total improvement value to $5,443,020 plus the land value of $2,726,806 for a total value of $8,169,826. Because of design and advanced preparation to minimize flood damage in the commercial areas a lower damage figure of 25% was used for calculation of loss potential. The estimated potential for additional dollars lost from commercial properties in Area 2 is $8,169,826 x 25% or $2,042,457.

Total estimated potential of additional dollars lost in Area 2:

Residential	$2,934,855
Commercial	$2,042,457
Total	$4,977,312

Note: The vacant parcels from Tonaquint Park east to I-15 were not considered in this study as they lie within the FEMA Flood Boundary as well as the EHB.

Study Area 3 - Virgin River from confluence southwest to St. George City limits.

Bloomington: This Neighborhood has the greatest number of meander land acres now under private ownership. The Virgin River has a wide bed as it flows through the Bloomington area and it has been known to make drastic course changes over the years. During the recent drought years, the large areas of open, dry ground have become very desirable for those with adjoining residences as pasture ground for animals and private picnic areas.

The land along the river is currently about 85% built out. City Parks and Trail systems are used throughout much of the flood plane lands. Though the recent flood waters threatened many of the homes along the river, no requests for market value tax relief were received by the County Assessor's Office. This indicates that any loss in value was restricted to the open meander land and temporary out buildings. The small area still available for development, but restricted because of the Erosion Hazard Boundary, would support approximately 9 to 10 residential dwellings units. The average price of homes within this area is $245,000. Improvement of these parcels could therefore have created an additional potential for loss of approximately 2,450,000 though this does not appear to be very probable based on the lack of actual damage reported in this area.

The Sun River development south of Bloomington also reported no damage from the recent flooding. A review of the area indicates that lands within the Erosion Hazard Boundary are being used for golf courses, parks and other open space, thus reducing the impact of potential flooding.

It is the appraisers opinion that no additional loss would be likely within this area had the additional available lands been improved.

Summary:

Area	Potential Loss
Area 1	-0-
Area 2	$4,977,312
Area 3	-0-
Total	**$4,977,312**


N
Area 1


N
Area 2

N
Area 3